Inferring spectral characteristics of the Hα spectral line observed by the Dutch Open Telescope Lyot filter

J. Koza, J. Rybák, P. Gömöry, A. Kučera

Astronomical Institute of the Slovak Academy of Sciences, Tatranská Lomnica, The Slovak Republic

Abstract: The poster presents a method of inferring of the Doppler shift, the core intensity, the core width, and the core asymmetry of the Hα spectral line observed by the Lyot filter installed on the Dutch Open Telescope (DOT). The spectral characteristics are inferred through the fitting of five intensity samples, separated from each other by 0.35 Å, by a 4^{th}-order polynomial, a Gaussian, and a parabola. We use the atlas Hα profile as a reference in estimating deviations of the derived spectral characteristics due to low spectral resolution and curve fitting. The Gaussian is the most preferable means for measurements of the Doppler shift with deviations smaller than 1 kms^{-1}. When using the 4^{th}-order polynomial, deviations are within the interval ±2.5 kms^{-1}, but it renders comparable deviations of the core intensity and the width as the Gaussian. The method and corrections are demonstrated using a sequence of 71 speckle-reconstructed five-point spectral scans of Hα taken by DOT on 19 October 2005 at the disk center of the quiet Sun.

Introduction and aims

The advent of the adaptive optics, the image reconstruction, and space-based observatories enabled usage of a tunable Lyot filter also in wide-field 2-D pseudospectroscopy of solar structures in two or more wavelengths in a spectral line profile. However, a few-point sampling of a spectral line profile with a very low spectral resolution evokes a question of an accuracy of extracted spectral characteristics. In general, an application of a Lyot filter together with a curve fitting may alter original characteristics to some extent. Therefore, it is desirable to know a quantitative estimate of this alteration. An aim of this study is to estimate deviations of the Doppler shift, the core intensity, and the core width of the Hα spectral line observed by the DOT Hα Lyot filter assuming two different transmission profiles.

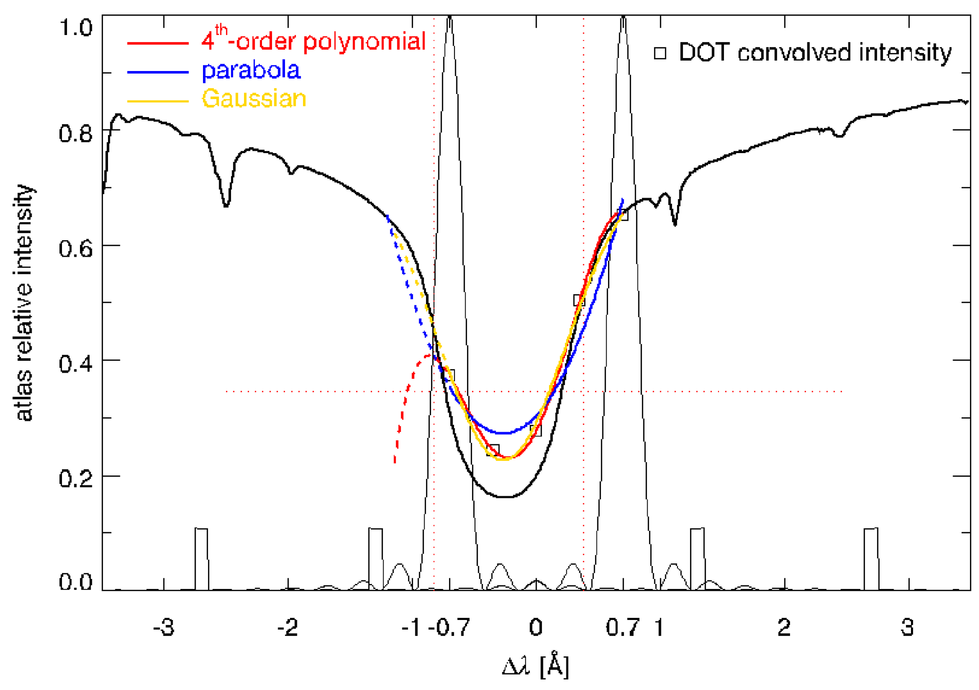

Figure 1. Example of the convolved intensities (squares) obtained from the atlas Hα profile redshifted by about -12 kms^{-1} and the $sinc^2 + \Pi$ transmission profile centered at 0, ±0.35, and ±0.7 Å (the last two shown) together with three intensity fits and their extrapolations (dashed) beyond -0.7 Å.

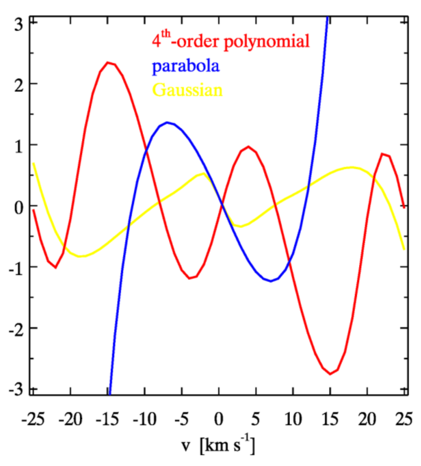

Figure 2. Deviations of the measured Dopper shift Δv for particular fitting curves with respect to the reference Doppler shift v of the atlas Hα profile.

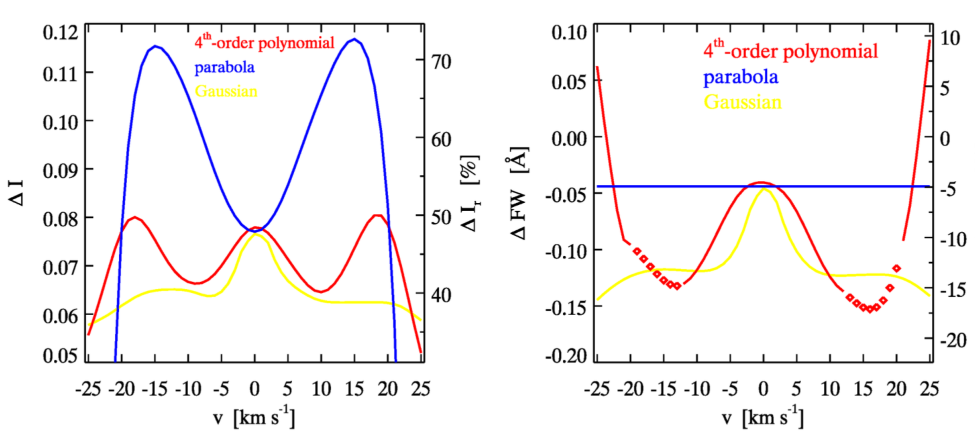

Figure 3. An absolute and relative deviations (left and right ordinates) of the core intensity (left panel) and fit width (right panel) with respect their reference atlas values for particular fitting curves at the reference Doppler shift v.

Method and spectral characteristics

As a reference, we adopt the disk-center Hα profile taken from the spectral atlas. The profile is shifted using Doppler velocities within the interval ±25 kms^{-1} with a step of 1 kms^{-1}. Then each of the 51 profiles is convolved with five $sinc^2$+Π transmission profiles located at 0, ±0.35, and ±0.7 Å from center of the atlas Hα profile. The resulting five convolved intensities are fitted by a 4^{th}-order polynomial, a Gaussian, and a parabola (Fig. 1). Then we determine the core intensity and Doppler shift of the fit minima with respect to the center of the atlas profile expressed in velocity units. Missing continuum intensity measurements near the Hα line preclude estimating the full width at half minimum of the original profile. To guess its core width from the convolved intensities, we introduce the fit width as the wavelength separation of the two fit flanks at half of the intensity range between the fit minimum and the average of the endpoint intensities at ±0.7 Å. Since in the following we aim to estimate the deviations of spectral characteristics obtained by particular fitting curves, we need to define their reference values considered as precise. Obviously, the reference of core velocity is the given Doppler shift of the atlas Hα profile. The reference of core intensity is the intensity minimum of the atlas Hα profile. We adopt as a references of fit width the value of 893 mÅ, which is the width of the atlas Hα profile at the average intensities of 0.32.

Results

Figure 2 suggests that the Gaussian fit should be the most preferable choice for measurements of the Doppler shift with deviations less than 1 kms^{-1} within the interval ±25 kms^{-1}. In the same interval, an application of a 4^{th}-order-polynomial fit results in considerably variable deviations ranging from −2.5 to +2.5 kms^{-1}. This is also the case of the parabolic fit within the interval of Doppler shifts of ±15 kms^{-1}. The left panel of Fig. 3 shows that all fitting curves overestimate the core intensity due to the effect of integration over the normalized filter transmission profile. The right panel of Fig. 3 shows that all fitting curves underestimate the fit width. Surprisingly, the parabolic fit exhibits a constant underestimate of the fit width and also the Gaussian fit displays an almost constant underestimate for Doppler shifts larger than 5 kms^{-1}.

Discussion

So far rarely used the 4^{th}-order-polynomial fit delivers comparable deviations core intensity and fit width as the Gaussian fit (Fig. 3). Its deviations of the Doppler shift are somewhat larger than those rendered by the Gaussian fit (Fig. 2), but contrary to a parabola, these are limited and defined within the whole interval ±25 kms^{-1}. However, a main technical difficulty in application of the 4^{th}-order-polynomial fit is its undulation at large Doppler shifts and an occurrence of local maxima. On the other hand, this curve allows estimating an asymmetry of a sufficiently sampled Hα profile.

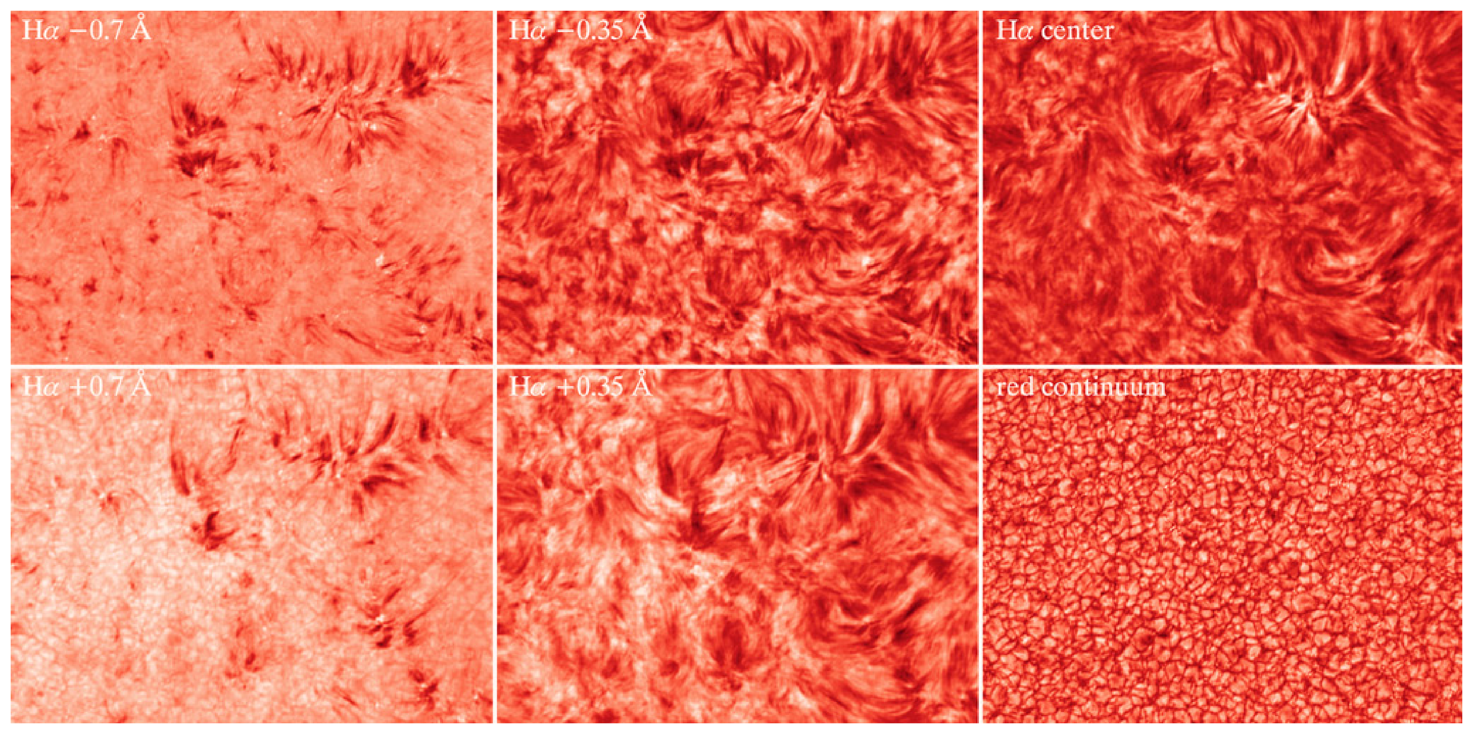

Figure 3. Hα and continuum images of the quiet Sun at the disk center taken by DOT on 2005 October 19.

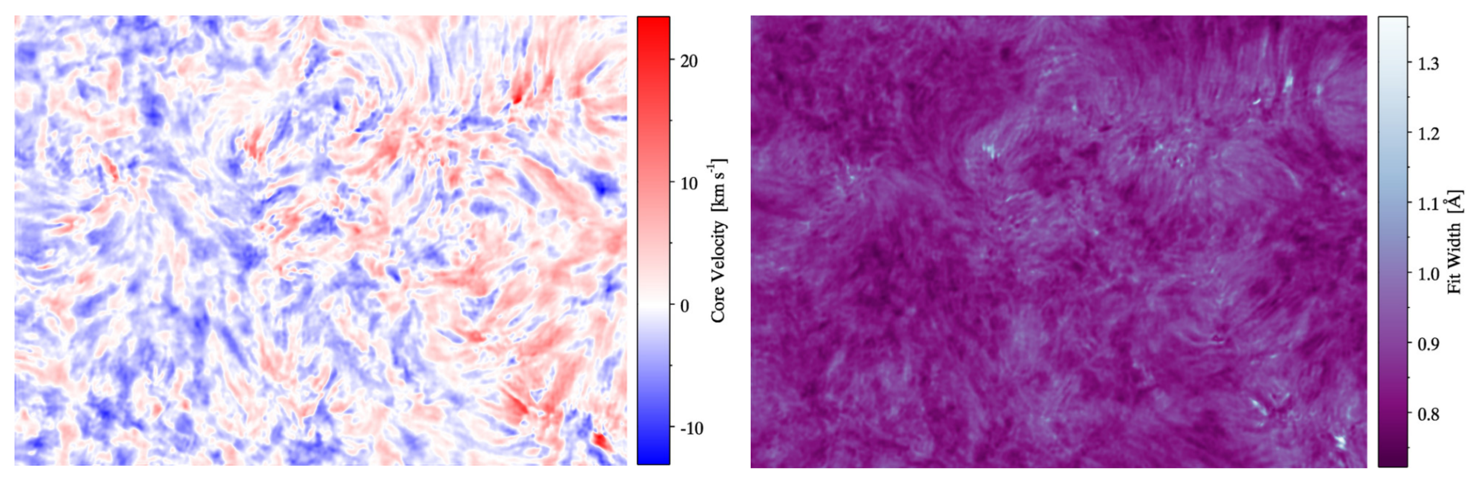

Figure 4. Core velocities and fit widths inferred from images in Fig. 3.

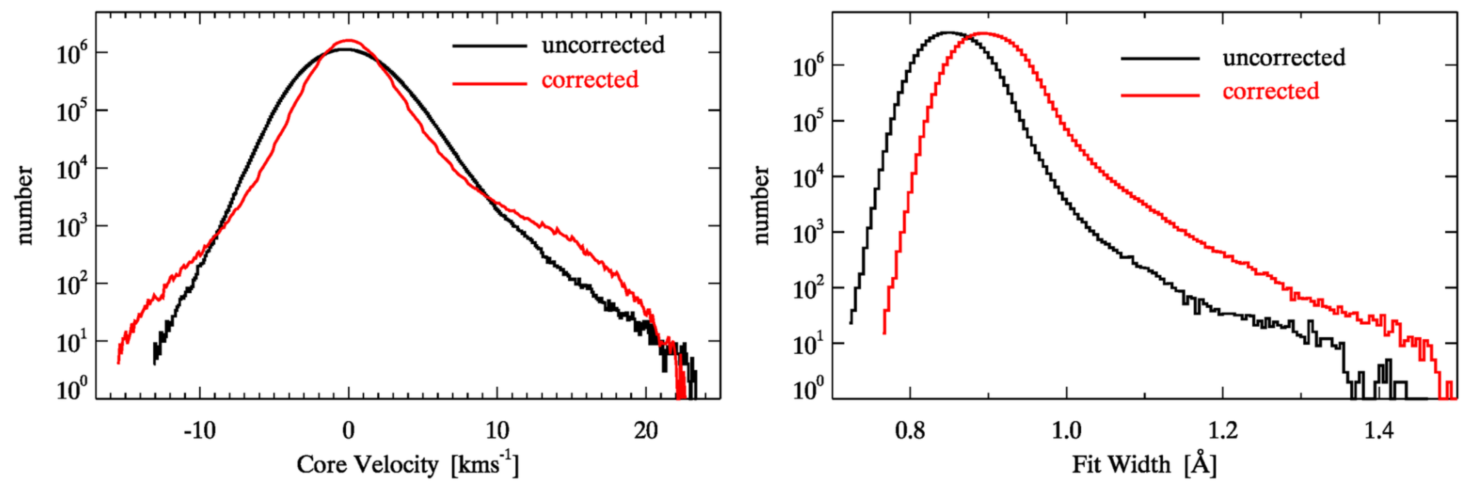

Figure 5. Histograms of original uncorrected and corrected core velocities and fit widths inferred from the DOT Hα datacube taken on 2005 October 19.

Application

We apply the results in correcting the spectral characteristics inferred from sequences of Hα images of a very quiet area near the disk center recorded by DOT on 19 October 2005 (Fig. 3). The sequence consists of 71 scans with 60-s cadence taken in five wavelengths across the Hα line profile: line center, ±0.35 Å, and ±0.7 Å. A time step between the five-wavelength scans of the Hα line profile is 60 s. Figure 4 shows uncorrected core velocities and fit derived from images in Fig. 3. Figure 5 shows histograms of their uncorrected values obtained from the whole 71-min long sequence and also values corrected by results shown in Figs. 2 and 3. An application of corrections narrows the distribution for core velocities less than 8 kms^{-1} but broadens it for larger velocities. This is due to highly-nonlinear sinus-like shape of deviations corresponding to the 4^{th}-order polynomial fit (red curve in Fig. 2). Corrections shift the distribution of fit widths towards larger values. While the peak of original uncorrected distribution is at 850 mÅ, the peak of corrected distribution is at 900 mÅ. This is due to underestimation of fit width by the 4^{th}-order polynomial fit.

DOT database

http://dotdb.strw.leidenuniv.nl/DOT/

Acknowledgments

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0816-11. This work was supported by the Science Grant Agency, project VEGA 2/0108/12. The Technology Foundation STW in the Netherlands financially supported the development and construction of the DOT and follow-up technical developments. The DOT has been built by instrumentation groups of Utrecht University and Delft University (DEMO) and several firms with specialized tasks. The DOT is located at Observatorio del Roque de los Muchachos (ORM) of Instituto de Astrofísica de Canarias (IAC). DOT observations on 2005 October 19 have been funded by the OPTICON Transnational Access Programme and by the ESMN-European Solar Magnetic Network - both programs of the EU FP6.

SKALNATÉ PLESO

SLOVAK RESEARCH AND DEVELOPMENT AGENCY